Date:	October 5, 2010
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Address:	600 B Street, Suite 800, MS 908A – San Diego, CA 92101
Project:	Task Order #19
Subject:	Avenida de la Playa Storm Water Pipe Preliminary Analysis

Tetra Tech, Inc. was hired by the City of San Diego, California to provide analysis and design services to improve drainage conditions associated with the storm drain outfall and storm drain pipes along Avenida de la Playa. The project is intended to address localized flooding issues in La Jolla caused by the inadequate storm drainage system. Several deficiencies are examined in the system, starting at the outfall structure and continuing upstream into the watershed serviced by the drainage system. The objective of this analysis is to identify design approaches that will eliminate inadequate discharge capacity at the outfall structure and control surface overflow due to the limited storm drain pipe capacity along Avenida de la Playa. This technical memorandum provides a description of the existing conditions, discussion of key issues, analysis of hydrology and hydraulics, and recommendations for improving the flooding issues in this area.

Background

The Avenida de la Playa storm sewer system serves to drain approximately 1.28 square miles of La Jolla Shores, a highly urbanized coastal hillside neighborhood in San Diego (Figure 1). Due to significant urbanization, steep slopes, and a highly developed storm drain network in the upper reaches of the system, the watershed is highly responsive to rainfall events, sending fast-moving surges of storm water downstream. Runoff from this watershed is primarily collected and conveyed in the underground storm drain system until it reaches the large series of pipes running along Avenida de la Playa where it discharges to a state-designated Area of Special Biological Significance (ASBS) via an outfall at the beach. Flooding problems are frequently reported along Avenida de la Playa between the outfall and the intersection with Camino del Sol (approximately 700 feet upstream).

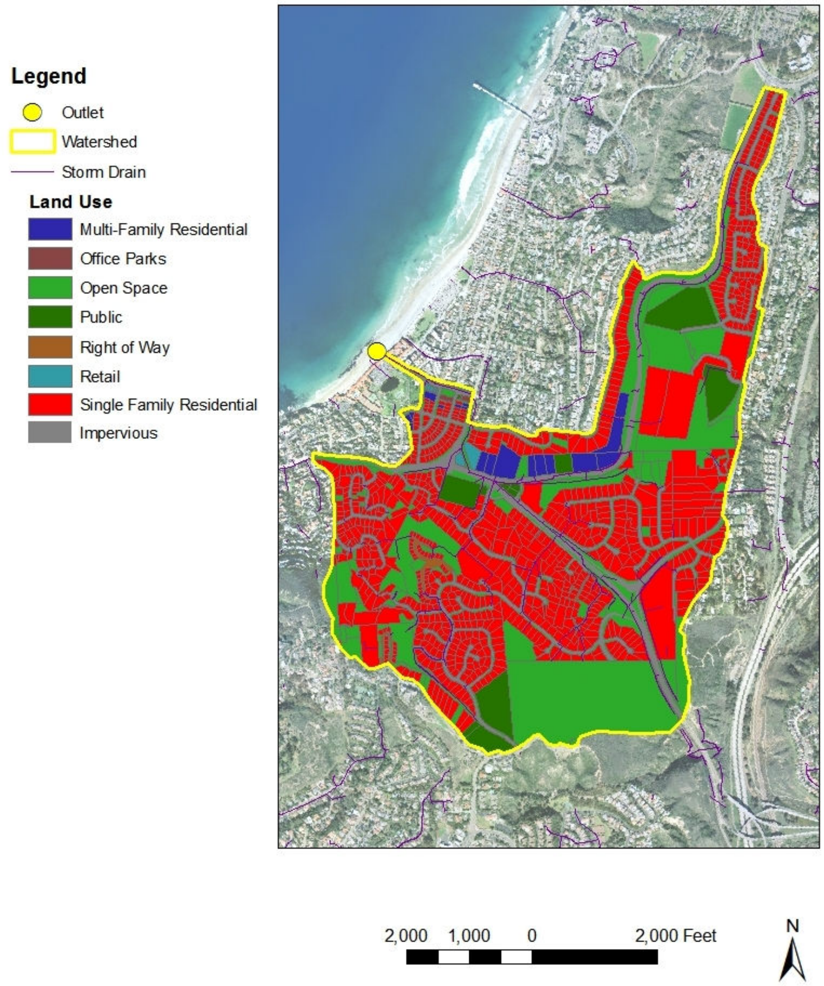

Figure 1. Avenida de la Playa Land Use

Storm Drain System

The Avenida de la Playa storm drain system was built in the late 1950's and comprises (from downstream to upstream) an outlet structure, 635 feet of twin parallel 51-inch diameter Reinforced Concrete Pipes (RCPs) with a slope of 0.2%, and a 72-inch RCP with a slope of 0.5% (Figure 2). Although the twin 51-inch diameter RCPs originally discharged directly onto the beach, the current outlet structure was added to prevent the discharge of trash and debris directly into the ASBS. The outlet structure consists of a concrete box with a wood deck cover and a grated opening on the downstream end that serves as a trash rack (Figure 3). The invert elevation of the twin 51-inch RCPs at the outlet structure is approximately 1.00 feet[1] (NGVD 29). One additional feature of the system is the dry weather flow diversion which is intended to direct nuisance flows into the nearby sanitary sewer system to avoid direct discharge to the ASBS.

[1] Estimated from ground surface topography

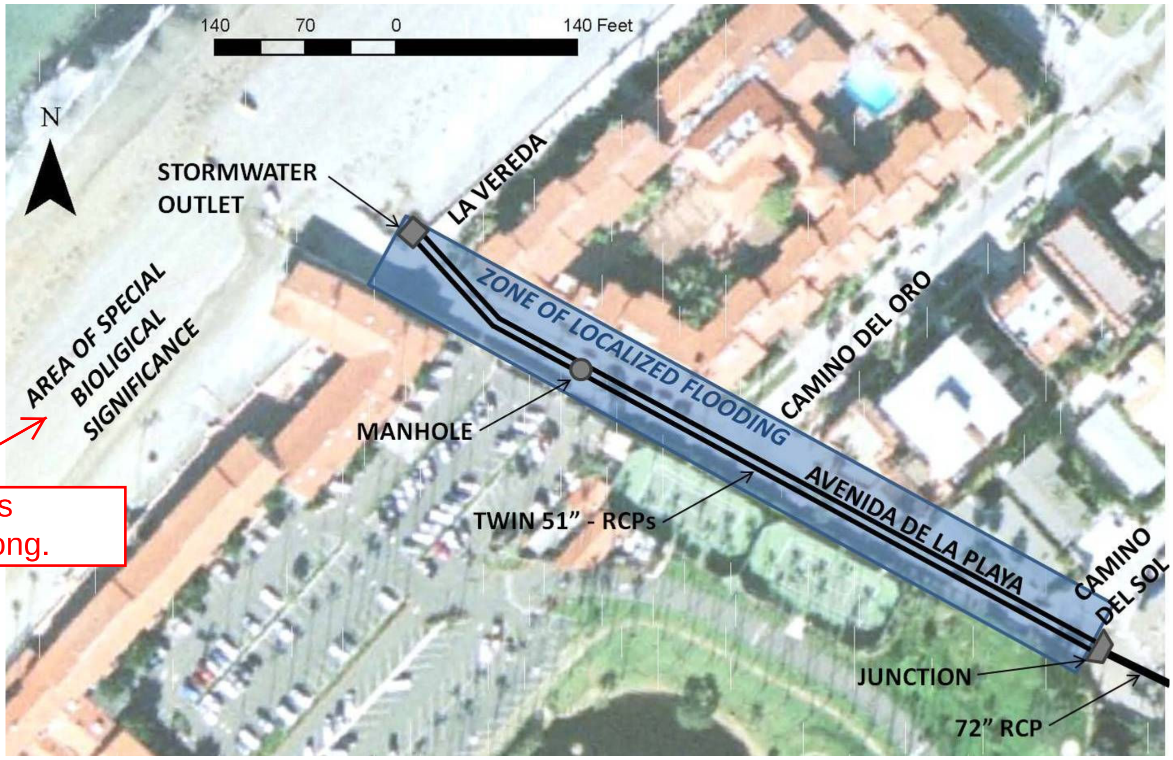

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Figure 2. Avenida de la Playa Storm Drain Layout

Figure 3. Outlet Structure

Causes of Flooding

During intense storm events, flow is restricted at or near the point of discharge, forcing water to back up in the storm drainage system and flood Avenida de la Playa. This flooding often results in dramatic consequences, such as overtopping of the outlet structure (Figure 4), a blown manhole (Figure 5), and road pavement failure (Figure 6), in addition to the impact of flooding on properties in the area.

Figure 4. Overtopping of the Outlet Structure

Figure 5. Flooding along Avenida de la Playa and Blown Manhole

Figure 6. Road Failure during Storm Event

The localized flooding is likely caused by a variety of issues. The overtopping of the outlet structure during storm events indicates that the discharge point is a limiting factor. Possible flow restrictions at the outlet include sand and sediment, trash build-up on the rack, and tidal influence; however, the extent to which each of these contributes to surcharged conditions is currently unclear. It is suspected that trash build-up and sedimentation are the primary influences on the hydraulic capacity of the outlet. Although tidal conditions are expected to periodically influence the localized flooding, it appears to be a secondary driver since the overtopping of the outlet structure is frequently observed during periods of low tide.

In addition to the outlet restrictions, the hydraulic capacity analysis included in Appendix A indicates that the twin 51-inch RCPs are significantly undersized for peak flows. The analysis shows that the twin 51-inch RCPs are only capable of conveying the 0.7 year storm event. Although this would not contribute to the overtopping of the outlet structure, larger storm events would not be effectively conveyed through the storm water system. This would back up water at storm drain inlets leading to more overland flow. Additionally, although the 72-inch RCP immediately upstream of the twin 51-inch RCPs consists of similar cross-sectional area and pipe material, the capacity of the 72-inch RCP is approximately double due to the increased slope and decreased wet surface area of the 72-inch section. ~~It is uncommon for storm water systems to decrease in capacity the further they are placed downstream in the watershed.~~ This choke point could be a considerable constraint contributing to the flooding of Avenida de la Playa, as evidenced by the observed flooding extents near the junction of the 72-inch RCP and the twin 51-inch RCPs (Figure 2).

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Changing land use in the watershed may also play a significant role in flooding along Avenida de la Playa. Increases in impervious surfaces in the watershed can increase both the peak flow and volume of runoff discharged during a storm event. Steep slopes (typical in this watershed) and efficient storm water collection points decrease the ~~lag~~ time ~~of~~ storm events, further increasing the peak flow at the outlet. The growing urbanization of a watershed effectively reduces the capacity of the storm sewer system to convey storm events. Hydraulic capacity is discussed in greater detail in Appendix A.

Analysis and Discussion

The causes of flooding include physical blockages at the outlet structure, limited capacity of the upstream storm sewer pipes, and land use changes within the watershed. Just as the causes of flooding are established from downstream to upstream, the solutions to the localized flooding should be prioritized from downstream to upstream. The overtopping of the outlet structure is an indication that its inadequate discharge capacity is directly related to flooding upstream of the outfall. The hydraulic analysis in Appendix A indicates that the capacity of the storm drain pipes likely also influences localized flooding issues. As discussed above, the objective of this analysis is to identify design approaches that eliminate inadequate discharge capacity at the outfall structure and control surface overflow due to the limited storm drain pipe capacity. The following sections discuss options to improve the outlet structure and the storm sewer pipe system to achieve this objective. As part of a complete assessment, options to improve the watershed condition and reduce storm peak flows are also discussed.

Outlet Structure

Trash and Debris Buildup

Figure 7 shows buildup of trash and debris at the outfall location. During storm events, trash and debris are transported by runoff flows through the storm sewer system, causing clogging at the outfall structure. The extent of the trash buildup within the outlet structure is shown in Figure 7. This extensive accumulation of trash reduces the capacity of the outfall structure.

Figure 7. Trash Buildup and Sedimentation at Outlet Structure

The Special Protections for ASBSs prohibit trash from being discharged from National Pollutant Discharge Elimination System-permitted storm water point sources. To prevent trash from discharging during storm events, trash would need to be either collected before it enters the storm sewer system or collected before the storm water is discharged onto the beach.

Collecting trash before it enters the storm sewer system requires the addition of screens on storm water inlets throughout the entire watershed, such as that shown in Figure 8. As an example, the Los Angeles Gateway Region Integrated Regional Water Management Authority is in the process of installing 12,000 trash-collection devices in the Los Angeles River watershed which are expected to remove 840,000 pounds of trash annually[2].

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[2] ZumMallen, R. Upstream Cities Get Pollution-Preventing Stormdrain Screens. Published 5 August 2010. Accessed 6 September 2010: http://www.lbpost.com/ryan/10232.

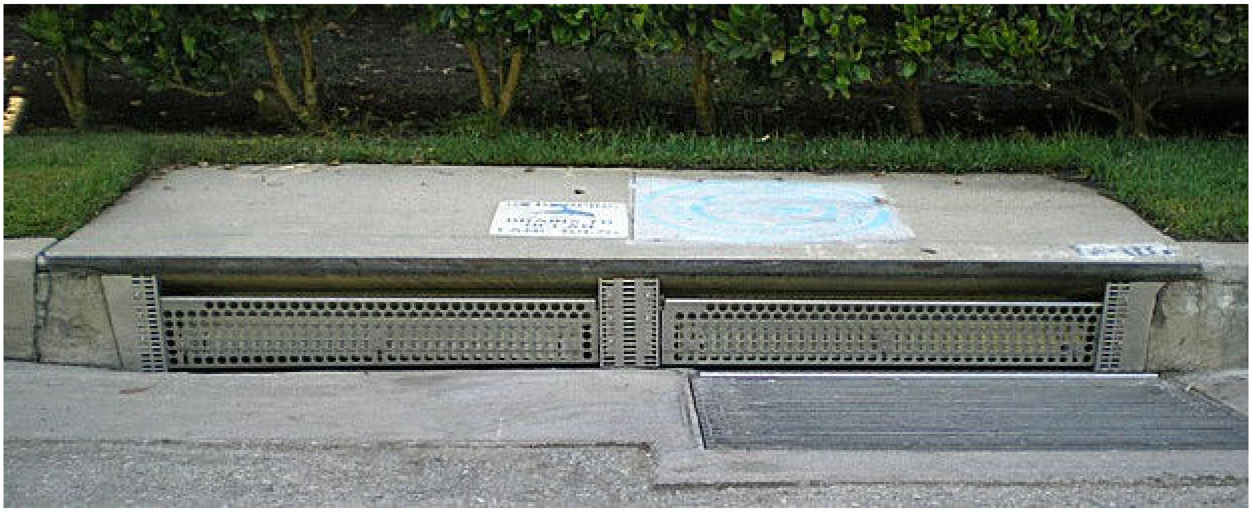

Figure 8. Storm Drain Screen (Photo courtesy West Coast Storm, Inc.)

Trash separation devices can also be installed throughout the storm sewer system. Hydrodynamic separators (HDS), or continuous deflective separators (CDS), are used to remove trash, sediment and oil from storm water flows. These devices (such as the one shown in Figure 9) can be placed either inline or offline but are limited to lower flow rates. An offline continuous deflective separator available from Contech Construction Products, Inc. can treat up to 300 cfs.

Figure 9. Continuous Deflective Separator (Photo Courtesy Contech Construction Products, Inc.)

An alternative to collecting trash at storm drain inlets would be to filter trash at the outlet before it discharges to the ASBS as is the current practice. The current outlet structure effectively collects trash during storm events but reduces the capacity of the outlet and causes overflow of the structure. A larger outlet structure with more surface area to filter trash would help alleviate problems with trash clogging the structure. A detailed analysis would need to be completed to determine the size of outlet structure required. This type of configuration is also limited by the occlusion of the outlet structure by the beach, which reduces the amount of surface area available for filtration.

Any type of trash collection system, whether it would be storm drain screens or continuous deflective separators or outlet filters, would require continual maintenance to ensure proper operation. Centralized trash collection systems, such as deflective separators or outlet filters, have the benefit of limiting the number of maintenance locations but may also clog more quickly, reducing their effectiveness and possibly backing up storm water in the sewer system.

Sediment/Sand

During high tide and dry conditions, wave action moves sand inland causing sedimentation in and around the outfall structure, substantially reducing the flow capacity. Normal beach sand elevations at the outlet, as observed during the site visit conducted on 18 May 2010, nearly completely occlude the twin 51-inch RCP outfall as shown in Figure 10. Figure 3 shows the extent of sedimentation around the outlet structure. City staff and local business owners present at the site visit reported that this sediment is partially flushed out during larger storm events only to be replaced during dry weather.

To prevent sedimentation in the outlet, the existing structure would need to be either reconfigured to keep sediment out or the outlet invert elevation must be greater than the normal beach sand elevation at the point of exit. Since raising the invert elevation of the pipe is likely impractical without raising the entire street for over 1,000 feet upstream, the pipe would have to be extended downstream to a point where the invert elevation met the normal sand elevation (thus becoming minimally affected by sediment aggradation due to ocean wave action). Extending the storm water outfall further onto the beach would not only incur additional infrastructure costs, which could be extensive, but it ~~could~~ also be subject to additional regulatory action. Additionally, if the outfall is extended below sea level, a flow prevention device would be needed to keep seawater and sea life out of the storm drain pipe during dry weather.

If the outlet structure is not moved, a mechanism must be included to either quickly remove the accumulated sediment during storm events or prevent sediment from entering the outlet structure during dry weather. One-way systems to prevent sediment from entering the outlet structure could include a louver system, such as the one proposed in the Preliminary Engineering Report[3], or duckbill style check valves, such as the one shown in Figure 11. Any one-way system incorporated to prevent sediment from entering the outlet structure would still be subject to occlusion during dry weather. If a one-way system is used with the outlet structure, a mechanism must be included to clear any sediment blocking the outlet during storm flows.

[3] "Avenida De La Playa Storm Drain Low Flow Diversion & Upgrades Preliminary Engineering Report (pp.44-45)," prepared by Gjaidan Stewart, dated May 4, 2009.

Sediment removal could occur mechanically through maintenance activities between storm events or hydraulically during storm events. Detailed design of the outlet structure would be required to determine what conditions would be needed to hydraulically remove sediment and how this would affect localized flooding along Avenida de la Playa.

Regardless of which technique is used to prevent sedimentation of the outlet structure, continual maintenance of the outlet structure would be required to ensure all components remain operational.

Figure 10. Sedimentation in Avenida de la Playa Outlet Structure

Figure 11. Duckbill style check valve (Photo courtesy Tideflex Technologies)

Tidal Influence

The Mean High Water[4], converted from the North American Vertical Datum (NAVD) to the National Geometric Vertical Datum of 1929 (NGVD 29), is listed at an elevation of 4.41 feet above the datum[5]. Based on the elevations of the outlet structure and tidal levels, the invert of the outfall is inundated during high tide conditions, causing a backwater effect in the storm drain system. This backwater effect will reduce the capacity of the system.

Visual evidence during storm events shows that the outlet structure is overtopped even during low tide conditions. While tidal conditions should be accounted for during future designs, it is not considered a primary driver of the localized flooding of Avenida de la Playa. Efforts to prevent sea water from entering the outlet structure should focus on sedimentation in the outlet structure caused by tidal conditions and wave action.

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Recommendations

While both trash build-up and sedimentation of the outlet structure result in reduced capacity of the outfall, they must be handled differently. ~~Trash is not allowed to discharge to the beach due to the Special Protections for the ASBS, effectively requiring a trash collection element as part of the system. To prevent the existing filter from clogging with trash during storm events, trash must be captured before it reaches the outlet structure.~~ Two options have been identified to limit trash and debris in the outlet structure: storm drain screens and continuous deflective separators. Storm drain screens would be placed on inlets throughout the watershed to limit the amount of trash entering the storm drain network. Alternatively, a continuous deflective separator would be located along a storm drain pipe and divert trash from the storm flow after it enters the storm drain network. Although storm drain inlets would be relatively easy to retrofit and could be added as part of a staged approach, a large number of storm drain screens would ultimately be required throughout the watershed and would need to be regularly cleaned to ensure proper operation. A continuous deflective separator would place trash collection at a central location but would require a higher initial cost and create a larger impact to implement. Although some CDS systems may be capable of treating up to 300 cfs, the massive size of such a system may be prohibitive for application in this area. Alternatively, several smaller HDS or CDS units may be strategically placed throughout the watershed to manage trash control in the system. The decision to choose a specific trash removal method for this project should be based on current funding opportunities and future maintenance capabilities. Maintenance activities may need to be expanded at the outlet structure to ensure it is continually cleared of trash between storm events.

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[4] Mean High Water is a tidal datum, defined by NOAA as the average of all the high water heights observed over the National Tidal Datum Epoch.

[5] As determined from NOAA's La Jolla, California tidal station, accessed 17 August 2010 at http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9410230%20La%20Jolla,%20CA&type=Datums

Alternatively, assuming the outlet structure is not moved due to regulatory and cost constraints, it is not possible to prevent sediment from affecting the outflow capacity of the storm drain system. Sediment will need to be continually removed to allow for discharge from the outlet structure; removal can be accomplished either mechanically or hydraulically. A duckbill style check valve prevents sediment from entering the outlet structure during dry weather and requires a small amount of head to open even when buried in sand. The outlet structure should be modified to include a duckbill style check valve system to address the sediment issue while maintaining a grated filter to address any trash entering the system.

Undersized Storm Sewer Pipes

As discussed above, results from the hydraulic capacity analysis included in Appendix A indicate that the storm drain system upstream of the outlet is significantly undersized. Peak flows for a range of design storms were calculated and compared to the capacity of the existing system (Figure 12). This comparison indicates that the Avenida de la Playa storm drain pipes reach capacity during the 0.7 year storm event. Statistically, the twin 51-inch RCPs that serve Avenida de la Playa would be expected to exceed capacity approximately 1.5 times per year even without the added complications associated with sedimentation, trash buildup, and tidal issues currently being experienced at the outlet.

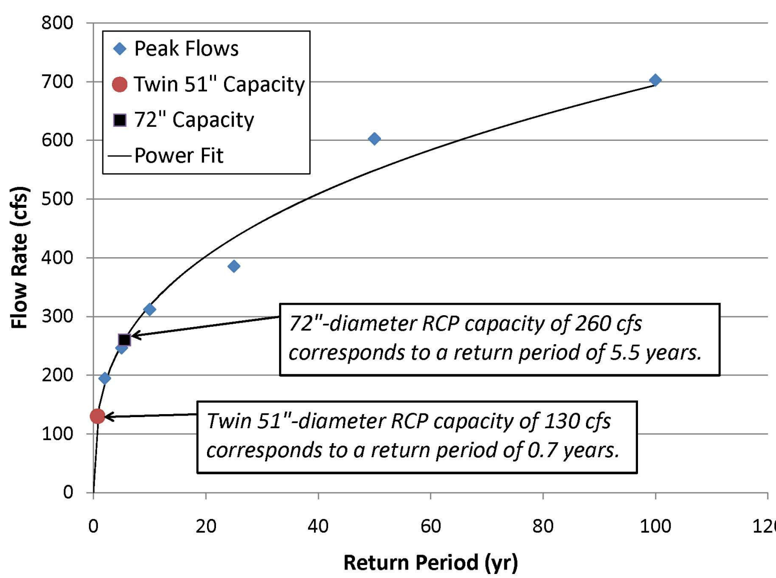

Figure 12. Modeled flow capacity of the twin 51-inch RCPs

Strom drain capacity can generally be increased by reducing pipe roughness, increasing the slope, or increasing pipe size. For the purposes of this study, however, due to the physical constraints of the surrounding development, site topography, and proximity to the ocean, it is assumed that modifications to the slope of the pipe are not possible. Additionally, potential capacity increases that could be realized from reducing pipe roughness are expected to be

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Based upon the calculated capacity deficit, approximately nine additional 51-inch RCPs identical to the existing pipes would be required to achieve the capacity of the 100-year storm event peak flow. While this would be infeasible due to cost and space issues, an increase in capacity is still recommended. At the very least, capacity should be increased to match the capacity of the 72-inch RCP immediately upstream. This increase in capacity could be achieved by installing two (2) additional 51-inch RCPs or the replacement of the existing twin 51-inch RCPs with twin 5-foot by 5-foot Reinforced Concrete Boxes (RCBs). This increased capacity results in the conveyance of the 5.5-year storm event peak flow, up from the 0.7-year storm event capacity in the existing configuration (Figure 12). The complete hydrologic modeling analysis of the Avenida de la Playa storm sewer system is included in Appendix A.

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Although space and cost constraints will limit increasing the size of the primary storm sewer system, secondary drainage systems might be available to mitigate the effects of larger storm events. The configuration of the road should be evaluated to identify possible improvements that could more reliably convey storm water overflows from the twin 51-inch RCPs. Modifications to improve flow conveyance could include lowering the roadbed to serve as an overflow flume or creating a conveyance channel within the roadway. Using the roadway as a secondary drainage system could cause additional issues, such as possible regulatory approval, conflict with utilities, and reinforcement of the roadway to prevent excessive erosion during overflow events. This approach should be evaluated during detailed design as a possible alternative to greatly increasing the storm drain capacity or as an additional component to help alleviate flooding along Avenida de la Playa.

A dry weather flow diversion, which eliminates discharge onto the beach between storm events, is required through the Special Protections for the ASBS. The dry weather flow diversion consists of a drainage pipe that diverts pollutant-heavy flows to the sanitary sewer system. The rehabilitation of a dry weather flow diversion would have little effect on increasing the capacity of the storm sewer system but is an important component of the ASBS regulations that would be easily incorporated during improvements to the storm pipe capacity.

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Recommendations

~~To further reduce flooding along Avenida de la Playa, it is important to increase the capacity of the storm drain pipes upstream of the outfall. According to the hydrologic analysis, the existing twin 51-inch RCPs are incapable of conveying the 100-year storm event.~~ While it is infeasible to increase the storm drain system to handle the 100-year storm event, the system should be increased to match or exceed the capacity of the upstream 72-inch RCP. This would require the addition of two (2) 51-inch RCPs or the conversion to twin 5-foot by 5-foot RCBs. The decision to choose between these two options should be based on the existing condition of the twin 51-inch RCPs, the space available for storm drain upgrades and the cost of adding storm drain pipes versus replacing storm drain pipes. Any upgrades to the storm drain pipe capacity should include the rehabilitation of the dry weather flow diversion, which is important to protect the quality of the ASBS.

Additional storm drain capacity should be obtained by evaluating secondary drainage systems. The Avenida de la Playa roadway should be redesigned to adequately convey flows during larger storm events. This might include lowering the road bed, creating a secondary drainage channel or reinforcing the existing roadway to prevent erosion. Detailed designs would be needed to determine the extent of the additional capacity available.

Land Use Changes

The Avenida de la Playa watershed is highly urbanized with steep slopes and an extensive storm sewer network. These components combine to prevent infiltration and decrease time to concentration of storm peaks, which results in a higher volume of storm water reaching the outlet structure in a shorter time period. This has exacerbated localized flooding along Avenida de la Playa.

An option to increase the "effective" capacity of the storm drain system is to reduce the peak flow runoff at the outlet by mitigating runoff farther up in the watershed. Peak flows can be reduced by detaining runoff in the watershed before it reaches the storm sewer system, encouraging infiltration into the local groundwater or slowly releasing storm flows into the storm sewer system. Detention facilities can range from the more traditional, such as ponds, to the more innovative, such as rain gardens (Figure 13), bioretention swales or underground storage. These detention facilities have the added benefits of providing water quality opportunities and reducing the amount of trash in the storm drain system.

Space, slope, and cost constraints make the addition of detention facilities in the watershed difficult. A full watershed assessment, including an analysis of soils and drainage paths, should be completed before locating and sizing any new detention structures.

Figure 13. Rain garden on steep slope (Photo courtesy EPA)

Recommendations

As part of a watershed-based approach to mitigate flooding along Avenida de la Playa, additional detention structures should be placed within the watershed to reduce the peak storm water flow at the outlet. Detention structures can consist of a broad range of alternatives at a variety of scales. A full watershed assessment should be performed to determine the size and location of any detention structures depending on infiltration capability, drainage paths and possible site constraints.

Conclusion

The overtopping of the outlet structure shown in Figure 4 indicates that the structure is not performing as designed and is a limiting factor in the Avenida de la Playa storm drain system. Yet the hydraulic analysis shows that the complications in the system could be caused by the undersized capacity of the storm drain pipes. Land use changes in the watershed have increased the amount of runoff, exacerbating capacity issues in the storm sewer system. Each of these three components plays a role in the localized flooding along Avenida de la Playa. Prioritization of these issues should begin at the outlet structure and move upstream, examining solutions at a local scale before moving to a watershed scale. The blown manhole, shown in Figure 5, and the overtopping of the outlet structure does give some indication that the outlet is a primary issue. The sedimentation occluding the structure and the trash build-up within the structure represent significant barriers to storm water outflow and these barriers should be addressed first.

Recommendations have been developed to reduce localized flooding along Avenida de la Playa. This goal will be achieved by alleviating inadequate discharge capacity at the outfall and controlling surface overflow due to the limited storm drain pipe capacity. These recommendations are included in the list below, in order of priority.

We are currently assessing inlet screens to see if we will allow them to be used.

1. Eliminate trash from the storm drain system before it reaches the outfall structure and clogs the filter. Install storm drain screens on inlets throughout the watershed or a system f continuous deflective separators along the storm drain system as close to the outlet as ossible.

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2. Retrofit the outlet structure by installing duckbill style check valves to prevent sediment from entering the outlet structure.
3. Increase maintenance activities in the watershed to ensure trash and sediment do not accumulate within the outlet structure.
4. Add two (2) 51-inch RCPs to the existing twin 51-inch RCPs or convert the exis 51-inch RCPs to twin 5-foot by 5-foot RCBs and rehabilitate a dry weather flow diversion to protect the ASBS.

The SOW is to add a second diversion further downstream because the existing one is not capturing all the dry weather flow.

5. Design a secondary drainage system along the Avenida de la Playa roadway to e convey overflows from the storm drain system.
6. Develop a plan to add detention structures and green infrastructure throughout the watershed to reduce stormwater peak flows.

Flooding along Avenida de la Playa is caused by a combination of three components, ranging from localized deficiencies to watershed-scale issues. Mitigation should be addressed by a multi-faceted approach which involves modification of the outlet structure, an increase in the capacity of the storm drain pipes and a decrease in the amount of runoff within the watershed. This watershed-based approach represents a more significant time and cost commitment but is an important step in managing storm water flows. By addressing issues at a multitude of scales, the city is able to take a holistic approach to mitigating the localized flooding along Avenida de la Playa.

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Even if the roadway could be redesigned to hold more flow, where would it be conveyed to? There doesn't seem to be anywhere to send it.

Appendix A

Hydraulic and Hydrologic Analysis

Hydraulic and Hydrologic Analysis

A full hydrologic analysis was performed for the Avenida de la Playa watershed to determine peak runoff flows and to evaluate the role of the storm drain pipes on the localized flooding issues. Full flow storm drain capacity was calculated using the Manning's equation and compared to the peak flow from the 100-year storm event, as determined from the hydrologic analysis. Additional storm events were evaluated to match the storm drain capacity with the corresponding storm event. This analysis illustrates that the Avenida de la Playa storm drain pipes are undersized and unable to convey larger storm events, possibly contributing to the localized flooding issues.

Background

The Avenida de la Playa storm drain system and outfall structure drains approximately 820 acres (1.28 square miles) into a protected area of the Pacific Ocean in La Jolla, CA (Figure A-1). The watershed is located in a highly urbanized area of the coastal precipitation zone.

The drainage area for Avenida de la Playa was modified from a previous delineation based on 2' contours and storm drainage network data provided in GIS format. Hydrologic analysis for Avenida de la Playa is based on procedures established in the City of San Diego Drainage Design Manual (DDM), which specifies the evaluation of the 100-year storm and the use of Soil Conservation Service (SCS) methods for drainage areas greater than one square mile.

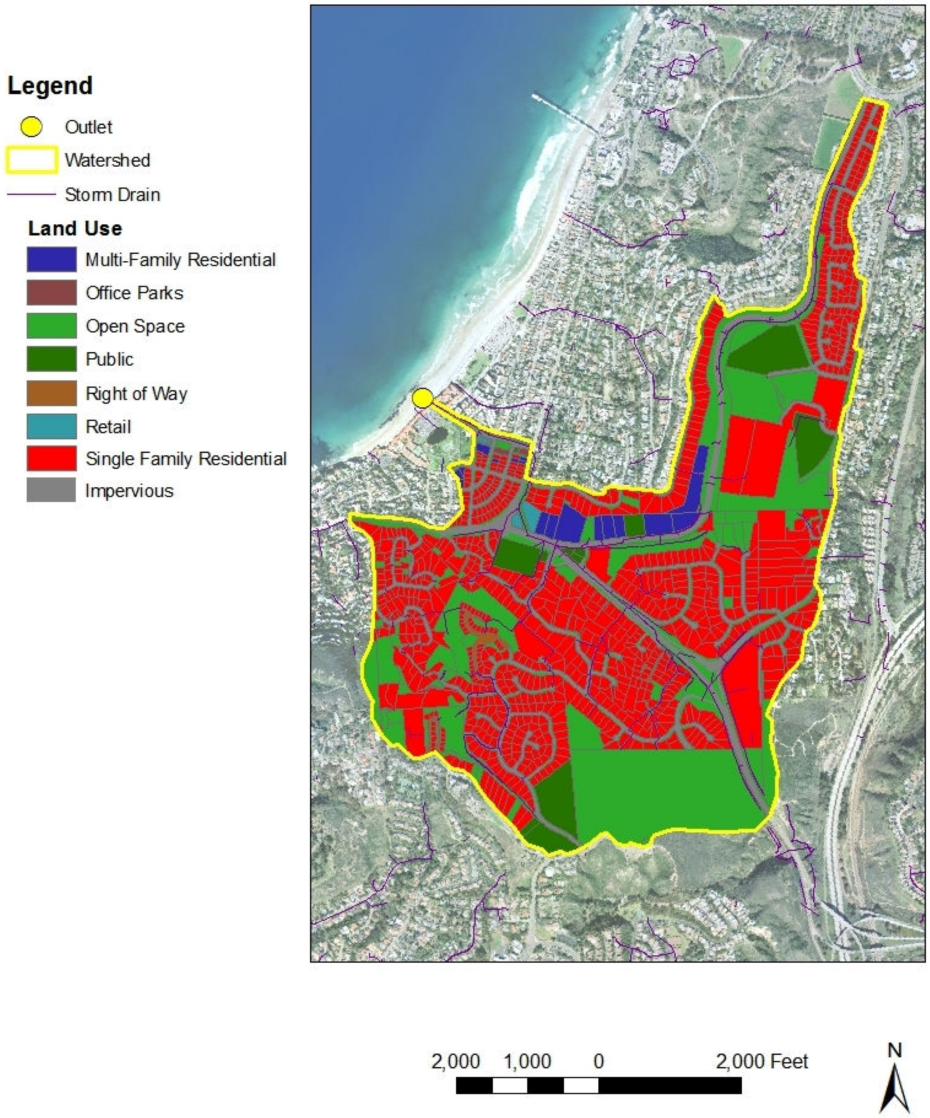

Figure A - 1. Avenida de la Playa Watershed

Land Use

Runoff curve numbers were obtained from the San Diego County Hydrology Manual (HM), which includes more detail on the urban environment and better represents the land use data available in the Avenida de la Playa watershed. Hydrologic Soil Group D soils were assumed throughout the entire watershed according to Section 1-102.2(4) of the DDM. Land use in Avenida de la Playa consists of primarily single family residential and open space as shown in Table A - 1 below. The curve numbers for each land use type as well as the watershed area-weighted curve number of 85.8 are also shown in Table A - 1. An average watershed imperviousness of 35% was determined from the land use characteristics.

Land Use	Area (ac)	Curve Number
Single Family Residential	407.0	85
Open Space	237.7	80
Impervious	98.4	98
Public	45.7	93
Multi-Family Residential	20.5	92
Right of Way	5.4	83
Retail	3.1	95
Office Parks	0.9	95
TOTAL	**818.8**	**85.8**

Table A - 1. Avenida de la Playa Land Use

Lag Time and Time to Peak

Lag time was calculated using the equation below, as specified in the DDM. The equation involves the length of the longest watercourse (L), the length of the longest watercourse measured upstream to a point opposite the center of area (L_C), the average Manning's roughness coefficient ($\overline{n}$) and the overall slope (S). The longest watercourse is taken along the path in the watershed that is hydraulically the farthest from the outlet. This path consists of overland flow, concentrated flow and pipe flow, all of which are accounted for in order to develop the average roughness coefficient.

$$T_{LAG} = 24\overline{n}\left(\frac{LxL_C}{\sqrt{S}}\right)^{0.38}$$

$$T_{LAG} = 24(0.022)\left(\frac{(2.41mi)(0.85mi)}{\sqrt{(168\,ft/mi)}}\right)^{0.38}$$

$$T_{LAG} = 0.26 \ \ hours$$

The Avenida de la Playa watershed is highly urbanized with a significant amount of impervious area directly connected to a well-developed storm drainage system. This results in an extremely short lag time for a watershed of this size. The time to peak was developed from the synthetic unit hydrograph as 0.862(T_{LAG}) or 0.22 hours. Since the time to peak was outside of the 0.4 to 4.0 hour range covered by the peak flow charts[6], HEC-HMS was used to determine the peak flow using the SCS methodology for a Type B storm with the parameters discussed above as required by the DDM.

[6] As discussed in the "Procedure for Using Peak Flow Charts to Compute Peak Flow" on p. 102 of the DDM

Rainfall

Rainfall depths for both the 6-hour, 100-year storm event and the 24-hour, 100-year storm event (2 inches and 4 inches, respectively) were determined from the precipitation maps included in the DDM. Rainfall hyetographs, using the Type B distribution modified by the rainfall depth, are included in Appendix B.

Peak Flow

The peak flow rate was determined by evaluating both the 6-hour and 24-hour storm events and selecting the larger of the two, as specified in the DDM. This resulted in a peak discharge of 514 cfs for the 24-hour, 100-year storm event and 703 cfs for the 6-hour, 100-year storm event. ***The peak flow of 703 cfs will be used for the capacity analysis at the Avenida de la Playa outfall.*** Hydrographs for the 6-hour and 24-hour, 100-year storm events are included in Appendix B.

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Capacity

In the capacity analysis it was assumed that the pipe was flowing full, free of obstructions and in good condition. This is an "idealized" capacity, which indicates whether the system is undersized for the current hydrology in the watershed regardless of any possible environmental conditions that would reduce the capacity. The capacity of the final conduit running full (twin 51-inch RCPs, slope S=0.002 and Manning's n=0.015) is 130cfs, meaning the pipes are under-designed for the 100-year storm. The capacity of the 72-inch RCP (S=0.005, n=0.015) is 260 cfs, also under-designed for the 100-year storm. (Idealized capacity equations are included below.) To determine the return period that corresponds with the capacity of the twin 51-inch RCPs, peak flows were calculated for the 2-, 5-, 10-, 25- and 50-year frequency storms using the same DDM procedures described above. (Hydrographs for the 2-, 5-, 10-, 25- and 50-year frequency, 6-hour Type B storm events are also included below.) A power curve was fit to these peak flows in order to assess the return period for the twin 51-inch RCPs (Figure A - 2). Based on this analysis, the Avenida de la Playa storm drain pipes reach capacity during the 0.7 year storm event. Statistically, the storm drain pipes that serve Avenida de la Playa would be expected to exceed capacity approximately 1.5 times per year even without the added complications associated with sedimentation at the outfall, trash buildup at the outlet and tidal influences.

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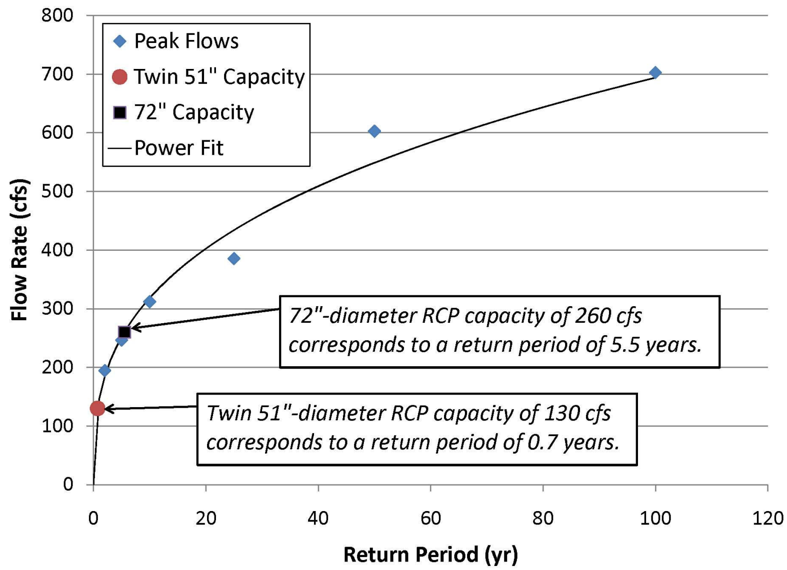

Figure A - 2. Return Period Analysis

To achieve capacity for the 100-year storm event peak flow of 703 cfs, nine additional – 51-inch RCPs would be needed at the same slope. Alternatively, it would require two (2) additional 51-inch RCPs or the conversion of the existing twin 51-inch RCPs or twin 5-foot by 5-foot Reinforced Concrete Boxes (RCBs) to meet or exceed the capacity of the 72-inch RCP located immediately upstream. This capacity corresponds to the 5.5 year event, as shown in Figure A - 2.

Conclusion

The Avenida de la Playa storm drain pipes are undersized and unable to convey the peak flow from the 100-year storm event. The existing twin 51-inch RCPs immediately upstream of the outlet structure are only capable of conveying the 0.7-year storm event although the 72-inch RCP located immediately upstream is capable of conveying the 5.5-year storm event. To adequately convey the 100-year storm event would require the addition of nine – 51-inch RCPs.

Appendix B

Hydrologic Figures

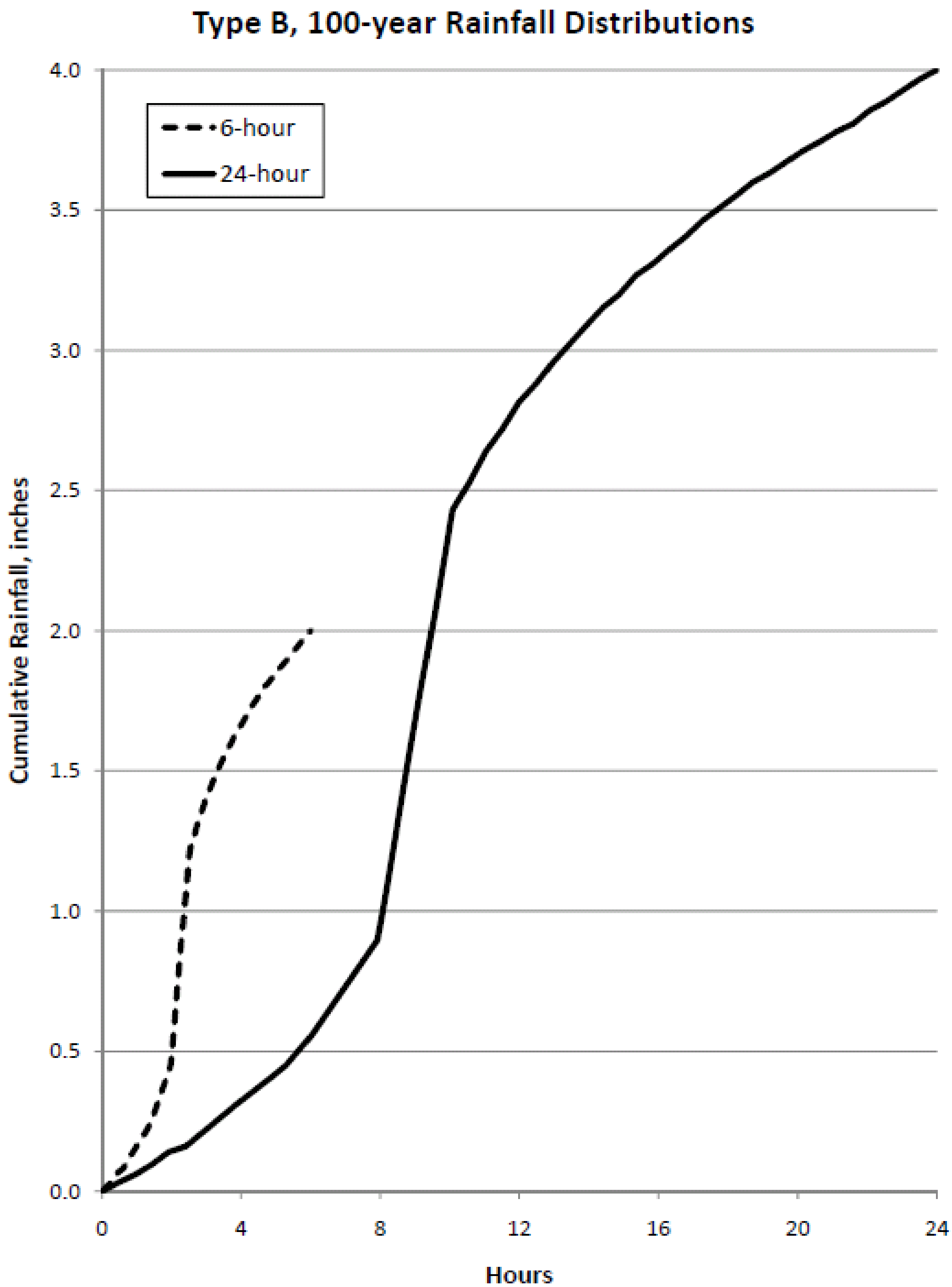

Figure B - 1. Type B 100-year Storm Rainfall Distributions

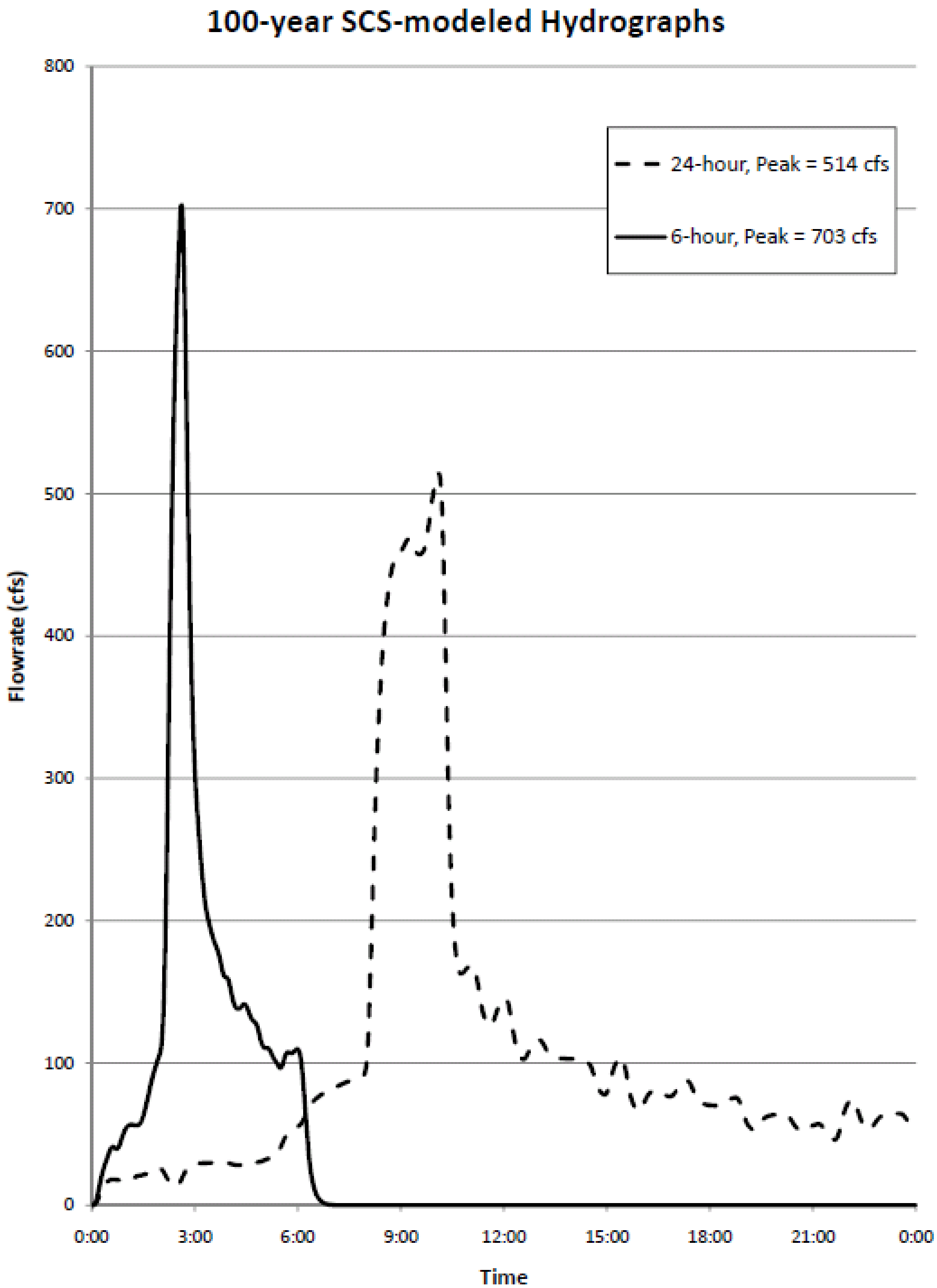

Figure B - 3. 100-year Storm Peak Flows